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THE DESIGN AND INSPECTION OF CERTAIN OPTICAL MUNITIONS OF WAR

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Read and discussed, 9th January, 1919

1. IT is with some diffidence that I venture to present this paper, but I feel that by means of it misunderstandings may be cleared up, the difficulties experienced by my department may be realized, useful hints as to improved methods of inspection may be evolved from the discussion, and possibly some of the tests to be described may be of use to those who did not know of them before.

To my mind the ideals governing design, manufacture and inspection should be as follows: Manufacturers, and those who deal with instruments, should know what classes of instruments are required and should submit to the authorities the highest class of designs of such instruments. The designs should be considered by a committee of experts who know what is really required, and what instruments best fulfil the conditions, both as regards use and facility of manufacture. This committee should after due consideration select the most suitable instrument to guide future manufacture. It would probably not arrive at a decision without having to embody details of one or more designs with those of another; probably also models of the modified design would have to be made, and experiments and trials carried out. Skilled designers and manufacturers would have to be consulted as to manufacturing details, the embodiment of standardized parts, etc. When the design was finally approved, the necessary specification and drawings would be prepared. After contracts had been placed, manufacturers would send in instruments which absolutely complied with the specifications. Having been minutely inspected by the manufacturers before despatch from their works, little inspection by the Inspection Department would be required.

I do not know if there is any country in the world where such ideals exist. I cannot honestly say that they do so in this country, except in a few instances.

Speaking generally, very few manufacturers have any idea as to what new instruments are required, and other people who put forward ideas have little knowledge as to how their ideas can be embodied in a practicable instrument.

When a new instrument is introduced it will be very costly to make, unless it is ordered in large numbers, on account of the expensive tools, jigs, gauges, etc. which will be required. Sometimes in the past, when a manufacturer has been asked to design and supply only a few samples of a new instrument, there is only too good reason to believe that he went to his scrap heap and selected bits which he could piece together and so form an instrument which to a certain extent complied with the requirements; but which could by no means be considered to be an ideal one. Later on when large supplies of the instrument were required, this 'scrappy' design would be perpetuated. This procedure is very unsatisfactory. The only remedy appears to be for the design to be really well thought out and adhered to, and for arrangements to be made with one or possibly more manufacturers to specialize in the production of the instrument, so that they may eventually make good the expenses which they have incurred in the purchase of special tools, etc. Again, if an instrument has to be modified or have additions made to it, its general design should be reconsidered.

When the specification and drawings have been prepared there should be no difficulty with the manufacture and inspection, provided that the manufacturers are efficient and thoroughly inspect their work, to see that it is correct, before they send it away. Unfortunately many firms do not appear to have their own inspection departments, but work upon the principle that it is cheaper for them to let Woolwich find out the defects than for them to keep an inspection staff for the purpose.

2. Instruments which are suitable for civilian purposes are often quite unsuitable for military purposes. This is probably much better realized now than it was a few years ago. It must be remembered that service instruments may be sent to any part of the world, and must remain serviceable when used in Arctic snows, Flanders mud, Mesopotamia heat, and desert sandstorms, or after travelling in lorries for thousands of miles over bad roads. In some cases they are attached to guns, and have to withstand the shock of firing. It must also be remembered that they are not always used by men who are used to handling delicate instruments, and that it is only on rare occasions that they can be sent to a workshop for repair.

Instruments must therefore be designed to withstand the above conditions; and the material must be tested, so far as is possible, to see that it will withstand any climate in the world. On the other hand the instruments must be as light as possible, especially those which have to be carried by men.

Sooner or later, certain parts of the instruments are sure to become lost or damaged, and it is of the utmost importance that spare parts, to replace them, should be available at base workshops. This means that certain parts must be strictly interchangeable.

In the past when small supplies of the same instrument have been obtained from several makers, it has been very difficult to insist upon all the makers making the large numbers of the component parts interchangeable with those made by another

maker. To do so would certainly have very greatly increased the price of the instrument. When the war broke out and large numbers of an instrument were required, it was too late to insist upon this interchangeability of a very large number of component parts. The result has been that supplies of certain parts at base workshops have had to be of two or three different patterns, so as to be interchangeable with those in the instruments made by two or three different firms.

There is little doubt that in any instrument which may be required in the future, much more interchangeability of parts will be insisted upon. This will be greatly assisted if standard dimensions of certain parts, e.g. binocular eyecups and prisms, lens cells, bubbles, mirrors, etc., are laid down. A committee, of which Mr. W. Taylor is the chairman, is now considering this question. It appears to be quite unreasonable that, say, three firms should make binoculars with prisms of almost exactly the same size, but which are just not interchangeable.

3. When an instrument has been approved for manufacture, a specification and drawings of it are prepared at Woolwich. The general principle upon which these are based is that the drawing shall show all dimensions, materials to be used, etc. and that the specification shall give all information which cannot conveniently be shown on the drawing. A typical specification will detail the following:

(1) What parts are to be accurately fitted, surfaced and shaped, etc.
(2) The optical data of the telescope, etc.
(3) Special points to be noted in connection with bubbles, magnetic needles, adjustments, etc.
(4) Weight allowed.
(5) Accessories to be supplied with the instrument.
(6) Details of the case.
(7) Composition of the alloys, etc. to be used, quality of the leather, silvering of mirrors, etc.
(8) Nature of screw threads to be used.
(9) List of parts which must be interchangeable.
(10) Detail of tests which will be applied to the instrument.

It is almost impossible to explain certain requirements in a specification and drawing alone, e.g. the definition of a telescope. In such cases a standard telescope is kept at Woolwich, and a note is made in the specification that the telescope to be supplied must have definition equal to that of the standard telescope. The curvature of the lenses and natures of glass to be used are not stated, but are left to the manufacturer. It is also difficult to test the tensile strength of small metal parts. To prevent inferior alloys being supplied the composition of the alloy is given in the specification, and a chemical analysis of any small part can be made if necessary.

4. The specification and drawings of an instrument having been prepared, and the authorities requiring a supply, manufacturers are asked to tender and eventually a contract is placed.

The manufacturer is then asked by me to send in a forward sample of the instrument, before completing the bulk of the supply. The object of this is to

ensure that a large number of instruments having the same defects may not be completed before the defects are discovered. There is always a possibility of some misunderstanding due to the drawing having been incorrectly interpreted, or to some vital point on it having been overlooked; or possibly the drawing may have an error in it. I understand that this procedure is not always very agreeable to the contractor who likes to turn out the parts in bulk, and who finds that making one instrument before the others is an inconvenience; but I am convinced by experience that the request for a forward sample is justified, and that it is only on very rare occasions that the forward sample is entirely free from defects.

When the forward sample arrives at Woolwich it is very minutely examined, and all discrepancies with the specification and drawings are noted down. The contractor is informed of the result and told which defects must be corrected in the sample, which in supply, and which should be corrected when convenient to him.

It sometimes happens that a contractor thinks that he can improve certain details in an instrument, and in many instances very useful modifications, both as regards serviceability and facility in manufacture, have originated in this way; but on the other hand contractors have sometimes introduced modifications which have been quite unacceptable, without any reference to me, with the result that considerable confusion and delay have been involved. As an example—some improvement in the design of an instrument may have been introduced, but the dimensions slightly altered, with the result that the instrument would not fit in the standard service cases for such instruments. Suggestions as to modifications are always welcomed.

5. I will now describe in detail the tests which are applied to instruments.

Optical properties of telescopes, periscopes, dial sights, etc. The specification usually lays down the magnification, field of view, effective aperture of O. G. and the angular field over which the definition must approach perfection. A variation from the standard optical data of plus or minus 5 per cent. is usually allowed.

With instruments of comparatively high power the magnification is usually measured by means of a dynameter. This (Fig. 1) consists of an outer tube with flange, for resting against the eyepiece of the telescope under test, and a tube which slides in it. At the front end of the inner tube is a lens *A* and at the rear end a Ramsden eyepiece which can be focussed. Mounted in the focal plane of the lens is a mother-of-pearl scale *B* which is divided into 50 parts. The magnification given by the front lens is so arranged that if a transparent scale is put in front of the flange, a quarter inch division on it will be covered by 50 divisions on the mother-of-pearl scale. Each division will therefore represent 1/200th of an inch. If a telescope is placed in front of the flange the diameter of its emergent pencil can be measured by seeing how many divisions on the mother-of-pearl scale cover it.

To use the dynameter: Focus the telescope for infinity, and the scale in the dynameter. Place the flange of the dynameter centrally on the eyepiece of the telescope. Move the inner tube of the dynameter until the object glass or a pin held against it is clearly seen in the dynameter. Note the number of divisions on the

scale which cover the bright circle which defines the effective aperture of the object glass. This number is the diameter of the emergent pencil in 200ths of an inch.

It is next necessary to measure the effective aperture of the object glass. This can be done by placing a transparent scale against it, looking at it through the dynameter, and reading off the length that is within the bright circle. It is, however, rather more accurate to place a pair of compasses against the object glass and set

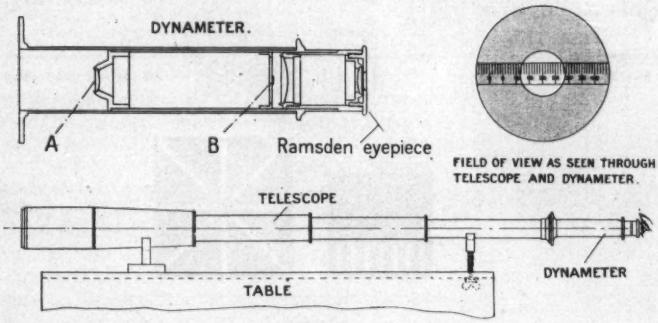

Fig. 1.

them until the points appear just to touch the edges of the bright circle and then to measure their exact distance apart. Or two small spots may be made on the object glass and their distance apart measured. The diameters of the emergent pencil and the effective diameter of the object glass having been thus measured, it is only necessary to divide the latter by the former to obtain the magnification.

The definition is tested by viewing a test board (Fig. 2) having various white markings on a black background, and perforated iron plates. One of the latter is covered with square and round holes of various dimensions, the other has long narrow slits radiating from its centre. It is found that these two plates afford by far the best means of testing definition. If it is perfect, the sides of all the holes and slits are well defined and no colour is seen in them. If the definition is poor, it is difficult to distinguish the round holes from the square ones, and they will all appear to be coloured. It, however, requires an expert to judge of the exact quality of the definition, as atmospheric conditions introduce difficulties. It is also very necessary that the dimensions of the holes should be of a suitable size for the magnification of the telescope. On one occasion a manufacturer was lent a telescope and asked to make one with equally good definition. When his telescope was examined at Woolwich its definition was found to be inferior, and the telescope was rejected. The firm's representative came to Woolwich and agreed that such was the case. The telescopes were then again compared by the maker at his works and the definition of the one appeared to be equal to that of the other. This pro-

cedure was repeated several times, and there was a chance of great friction arising between the manufacturer and Woolwich, when it was ascertained that the holes

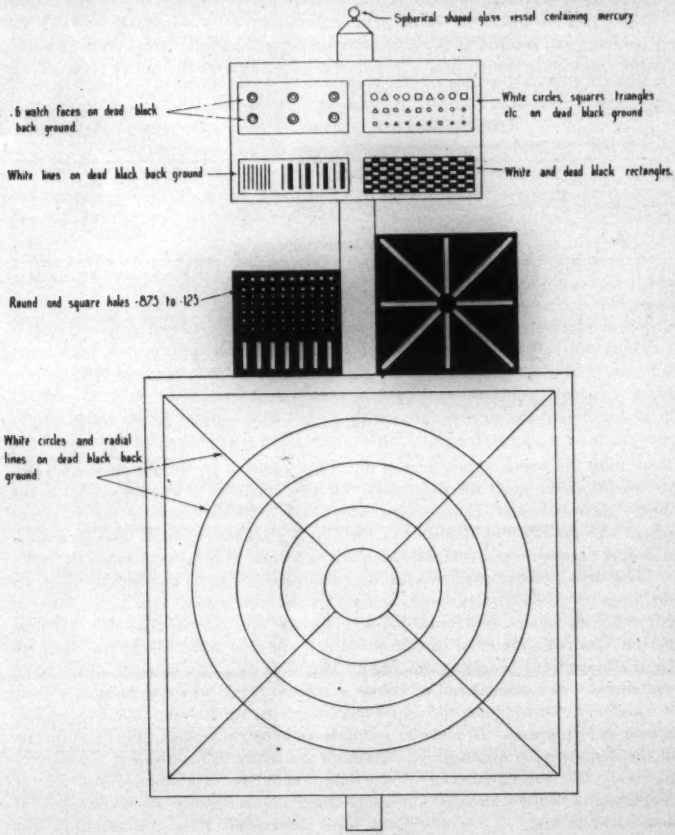
Spherical shaped glass vessel containing mercury
6 watch faces on dead black back ground.
White circles, squares triangles etc. on dead black ground
White lines on dead black back ground
White and dead black rectangles.
Round and square holes .875 to .125
White circles and radial lines on dead black back ground.

Fig. 2. Test Board.

in the plate at the manufacturer's works were all large ones and did not show up the bad definition; the small holes in the plate at Woolwich showed it up at once.

Speaking generally, the definition of a telescope for observing fire, etc. should

be as nearly perfect as possible over the whole field of view; whereas that of a telescope having cross wires or a pointer should be as perfect as possible near the intersection of the cross wires or the tip of the pointer, and sufficiently good over the remainder of the field for picking up the target. During use, refocussing for different portions of the field is, of course, not permissible.

When a telescope is being tested, the perforated plate is brought into the centre of the field and the telescope accurately focussed on it. The telescope is then elevated and traversed, so that, without the focus being altered, the definition over all parts of the field can be examined.

The field of view is tested by viewing a graduated scale 50 or 100 yards away from the telescope, and noting how many graduations can be seen at one time; or a collimator with a graduated scale can be used.

The Zeiss machine, referred to later on, allows of the field of view of binoculars being tested at the same time as the parallelism of the optical axes and the magnification.

The normal focus of a telescope is tested by means of an auxiliary telescope having a magnification of about six diameters (Fig. 3). The auxiliary telescope, having been accurately focussed on a distant object, is placed immediately behind the eyepiece of the telescope to be tested. The two telescopes are then directed on to a distant object or the cross wires of a correctly adjusted collimator. The eyepiece of the telescope which is under test is then adjusted so that the distant object or the cross wires in the collimator are in perfect focus. The diopter scale should then be found to read zero.

The accuracy of the graduations of the diopter scale are then tested by setting the scale at different readings, and placing standard spectacle lenses of the same diopter number, but of different sign, between the two telescopes. The distant object or the cross wires in the collimator should, of course, be still in focus.

Parallax is tested by laying the telescope on a small distant object, removing the eyeguard from the eyepiece, and moving the eye in rear of the eyepiece. The intersection of the cross wires should, of course, remain

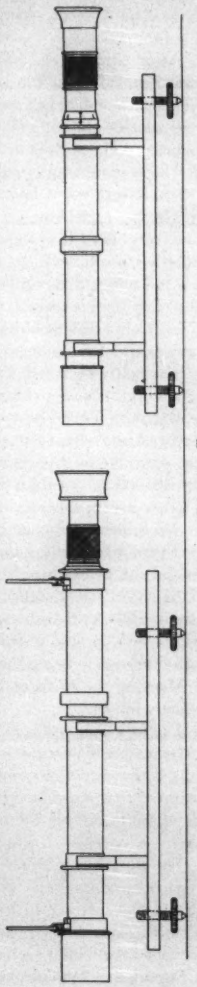

Fig. 3. Telescope Test.

on the distant object. Parallax is also often tested by means of a collimator instead of a distant object.

At one time there was considerable difficulty in specifying the thickness of graticules and cross wires. All recent specifications lay down that when lines or rods, a certain distance away, are viewed through the telescope the breadth of the cross wire or graticule must be such that it just covers a line or rod of a certain diameter, and just does not cover one of a slightly larger diameter.

The spacing and length of graticule lines are tested by laying the telescope on a suitable scale.

The cross wires of some telescopes are illuminated by means of a small electric glow lamp, fixed in a socket in rear of the diaphragm. The socket has to be very accurately positioned. Its accurate positioning can only be tested by trying a lamp in it and noting if the cross wires are effectively illuminated.

Collimation is usually tested by supporting the telescope on suitable bearings, laying it on a distant object and slowly revolving it. The intersection of the cross wires or tip of the pointer should, of course, remain on the distant object.

The test with which there has been most trouble is without doubt that to ascertain if graticules, prisms and lenses in enclosed instruments are likely to become covered with film. Many instances have occurred in which instruments have been approved and sent to store, and after a few weeks there have been found to be very defective in this respect. All these things are rather difficult to detect. Experience has shown that, if there is the very slightest sign of the formation of film in a new instrument, it is likely to increase.

Much information as to the condition of things inside the instrument can often be obtained by looking through the object glass end. The condition of the diaphragm can be examined by looking through the eyepiece and gradually covering up the object glass, so that one is not dazzled by excess of light. The very slightest trace of film can then be seen. Field lenses, with which there has been particular trouble, can be best tested in the same way; the eyepiece being slowly revolved whilst the test is being made.

Many of the surfaces of prisms, etc. can be brought into focus by means of auxiliary lenses.

The following are some of the principal mechanical tests of telescopes:

Diameters of bearing rings are tested by means of a micrometer. It is not always realized that with telescopes which are subjected to the 'end for end' test it is necessary that the diameter of both rings should be absolutely the same, or the axis of the telescope will not be horizontal when the bubble is in the centre of its run.

The interchangeability of parts in such telescopes as the Signalling telescope is tested by trying each part in a gauge and seeing that it is a reasonable fit. It is realized that this test is not ideal if very large numbers of parts are to be tested, unless the gauges are constantly being examined and replaced when worn; but it is hoped that better methods will soon be available.

Signalling telescopes and others with draw tubes are also tested to see that

certain spring boxes, etc. have been firmly soldered in position. This is done by extending them somewhat violently.

Certain sighting and other telescopes are tested to see that the collimation and similar adjustments are stable. After having been adjusted, the telescope is carefully attached to a vibrating machine which consists of a hinged board resting upon an eccentric having a throw of about $1\frac{1}{2}$ inches. The eccentric is revolved by a motor about 400 times a minute.

One of the chief tests which all sealed up instruments, e.g. prismatic telescopes, binoculars, periscopes and No. 7 dial sights, must withstand is a water test. The instruments are laid out and a shower of water from a tap and rose is allowed to fall on them. The shower of water is made to represent a tropical rain storm.

I have not mentioned any tests as to the weathering qualities of the glass which is used for the lenses, prisms, etc. the reason being that I do not yet know of any really satisfactory tests. Mr Elsden of the Chemical Inspection Department at Woolwich is however carrying out very elaborate experiments with the view of establishing tests which can be considered to be really reliable. Very promising results have been obtained and it is hoped that before long definite tests will be laid down in specifications.

Certain instruments are submitted to a heat test, to see if they are capable of withstanding tropical climates. This usually consists in gradually heating them for some hours in copper chambers up to a temperature of, say, 110° F., a certain percentage being heated up to a considerably higher temperature. The object of this test is to see that the lubricants used do not get too soft or run, that the glass does not film, and that the balsaming of lenses and silvering of prisms does not deteriorate.

6. Although the tests for periscopes are practically the same as those for telescopes, binoculars require additional ones. The principal one is to ascertain that the optical axes of the two bodies are parallel to one another at all interocular extensions. In other words, they must both be parallel to the axis of the hinge. The following are typical testing instruments:

The Service pattern (Fig. 4) must be as light and compact as possible. It consists of a base at the front end of which are mounted two parallel collimators with

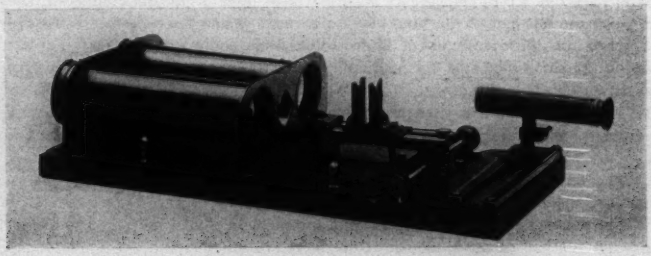

Fig. 4. Apparatus for testing Binoculars. Service pattern.

cross wires, a table for supporting the binocular under test and a telescope with cross wires, which can be moved along a slide near the rear of the base. The binocular under test is placed on the table and the telescope is brought in line with, say, its right eyepiece. The table is then elevated and traversed until the cross wires in the telescope are seen to coincide with those in the right collimator. The telescope is then slid to the left until it is opposite the left eyepiece. The cross wires in the telescope and left collimator will then be found to be in coincidence if the parallelism of the binoculars is correct.

A very convenient form of instrument was purchased from Messrs Zeiss some years ago (Fig. 5). It is arranged as follows: Along a slide, triangular in section and about 1 metre in length, three pieces can be slid. Upon these are mounted a double collimator, a table for supporting the binocular under test, and a double testing telescope. The heights of the different parts can be adjusted as required. In the focal planes of the collimators are diaphragms having horizontal and vertical cross lines, the horizontal line being divided, in tenths of a degree, up to 5° right and left of the centre (Fig. 6). At the rear end of each collimator is a rhomboidal prism which can be revolved, and so allow of binoculars having object glasses at different distances apart being tested. The mountings of the two prisms are geared together so that they will move through the same distance in different directions.

The table upon which the binocular under test is supported has slow motion elevating and traversing movements.

Each of the testing telescopes has a diaphragm divided up in the same way as those in the collimator, i.e. in tenths of a degree; but they are numbered from 0 to 12 degrees (Fig. 6). The right diaphragm has also marked upon it two rectangles which indicate the permissible error of parallelism with a binocular having a magnification of 6 diameters. The small rectangle represents errors of 2 minutes away from hinge, 6 minutes towards hinge and 1·5 minutes up or down. The diaphragm in the left binocular can be revolved through 90°, so that the scale can be set vertically if required.

When a binocular is to be tested, it is focussed for infinity and placed on the supporting table. The table is then manipulated until the cross lines in the left-hand telescope are in coincidence with the cross lines in the left collimator, seen through the left half of the binocular under test. When the right-hand telescope is looked into, the intersection of the cross lines in the collimator must be somewhere within the small rectangle on the diaphragm of the testing telescope, or the error in parallelism is too great.

The magnification is then tested by noting how many divisions on the diaphragm of the testing telescope cover one division on that of the collimator. It is also noted if the two halves of the binocular have the same magnification.

The zero and graduations of the diopter collars are then checked by placing standard spectacle lenses in front of the testing telescope.

The testing telescope is then removed, and the field of view measured by looking through one half of the binocular at one of the collimators and noting how many divisions in the latter can be seen at one time.

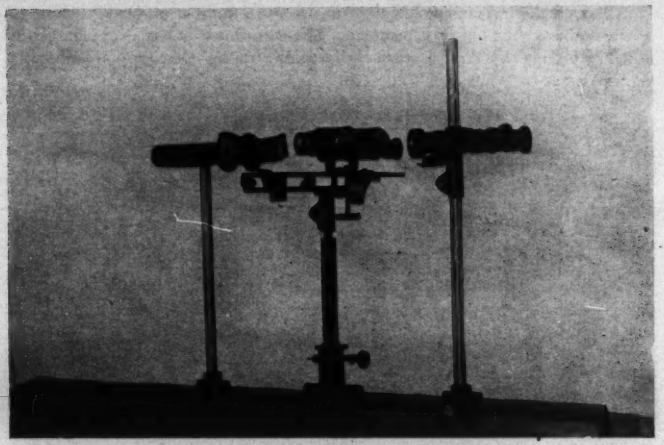

Fig. 5. Apparatus for testing Binoculars. Zeiss pattern.

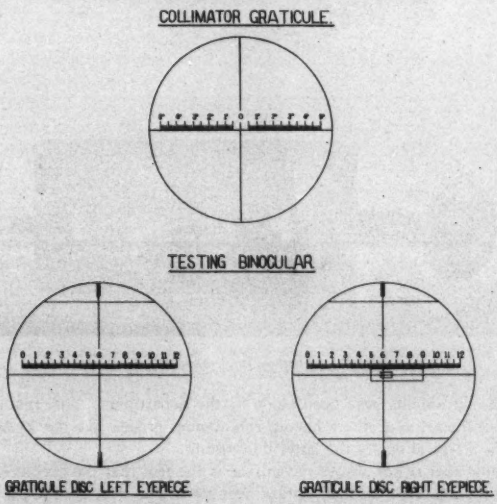

Fig. 6. Apparatus for testing Binoculars.

Although the instrument has been in use for a number of years, it does not appear to have gone out of adjustment. The adjustment at any extension can be tested by placing rhomboidal prisms between the testing telescope and collimator.

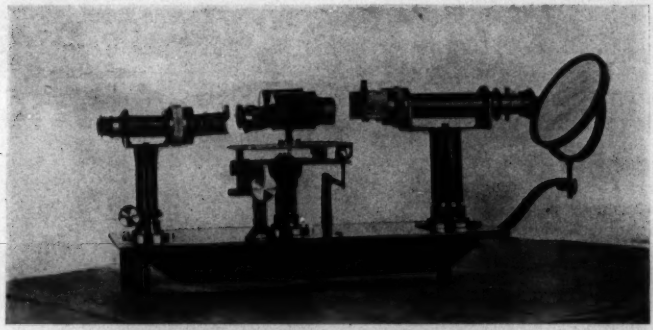

Fig. 7. Apparatus for testing Binoculars. Woolwich pattern.

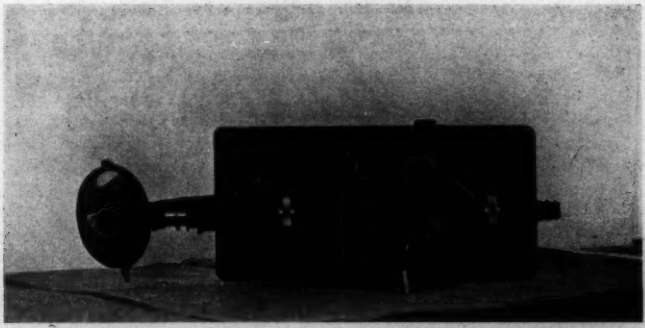

Fig. 8. Apparatus for testing Binoculars. Woolwich pattern.

Several instruments have been made by the department, some resembling the service instrument, and others having rhomboidal prisms like the Zeiss. Figs. 7 and 8 show a typical one of the latter description.

One thing that is not always recognized is the fact that the eyepieces must be accurately mounted so that their optical axes are in line with the optical centres of

the object glasses, otherwise when they are focussed the parallelism of the two telescopes will be thrown out.

With prismatic binoculars and telescopes it is important that the image is perfectly upright. In other words, if a plumb line is seen with one eye through the telescope and with the other eye direct, the two images must be parallel to one another. If they are not so, the defect is due to the prisms not being mounted exactly at right angles to one another.

The interocular extension is measured, by means of a pair of callipers, between the left-hand or right-hand edges of the two eyelenses.

In some binoculars the prisms are adjusted by means of screws which press either directly upon them or upon thin metal covers which partially surround them. Such adjustments are dangerous as, if the screws are screwed too tightly home, a lowering of the temperature will contract the metal bodies and exert a very great pressure upon the prisms. To ascertain whether the screws are exerting too much pressure, polarised light from a pile of glass plates is passed through the binocular into a Nicol prism, in which the strain can easily be seen in the form of black or coloured markings.

7. The principal tests for directors and similar instruments are for ascertaining the accuracy of the azimuth and altitude scales, to see that the pivots and other parts are accurately fitted, and that the bubbles, compasses, etc., are accurately mounted.

The apparatus shown in Figs. 9 and 10 is used for testing the azimuth scales. It consists of a base plate with worm wheel and azimuth scale, above which is mounted a frame to which various adapters for different instruments can be attached. A micrometer, to read single minutes, is attached to the frame. A collimator with cross wires is set up a short distance away from the testing apparatus.

The instrument to be tested is set at zero and attached to the adapter. The testing apparatus is also set at zero. The cross wires in the instrument under test are then 'layed' on those in the collimator without altering the setting of any of the scales. The instrument under test is then set to any desired azimuth reading and the testing apparatus is set to the same reading but in the opposite direction. The cross wires of the instrument and of the collimator should then again be found to be in coincidence. If they are not so, they can be brought into it, and the error noted. An error of 1 or 2 minutes is usually allowed.

Backlash is tested by 'laying' the telescope on the cross wires in the collimator, moving it first from the right and then from the left. The difference between the readings obtained is the amount of backlash.

The zero of the altitude scale is tested by setting the scale to zero, bringing the telescope bubble to the centre of its run, and seeing if the horizontal wire in the telescope is coincident with that in the collimator. The graduations of the altitude or clinometer level scales are tested by 'laying' the telescope on a vertical scale some distance away, and seeing if the bubble is in the centre of its run when the altitude scale reads the same angle as the scale on which the telescope is 'layed.'

When the instrument has been accurately levelled by means of its telescope

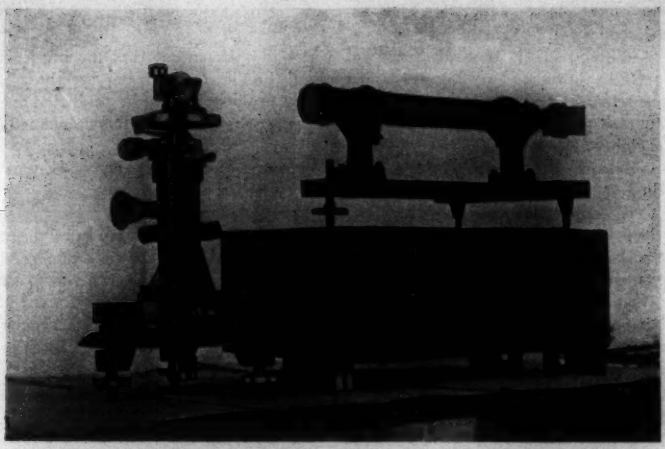

Fig. 9. Apparatus for testing Azimuth Scales.

bubble or clinometer level, the mounting of the body bubbles is tested. The air bubbles should be in the centre of their runs, and remain so whilst the instrument is slowly revolved through a complete circle.

The adjustment of the magnetic compass is tested by 'laying' the telescope on

Fig. 10. Apparatus for testing Azimuth Scales.

a point which is known to be in the direction of the magnetic north. The needle must then point to its zero.

The metal of the instrument is usually tested by means of a compass to see that it is non-magnetic, as the brass used sometimes contains traces of iron.

In some of the more accurate instruments it is very necessary to test the fit of the main coned pivot. To prevent disputes as to what is a perfect fit, the specification usually lays down that a pencil mark will be made along the pivot which will then be inserted in the socket and revolved. The pencil mark must be completely obliterated. Some instruments, e.g. the No. 5 director, have two vertical pivots whose axes should be in line with one another. Their alignment is tested by 'laying' the telescope on a collimator and revolving the part which is connected to both pivots.

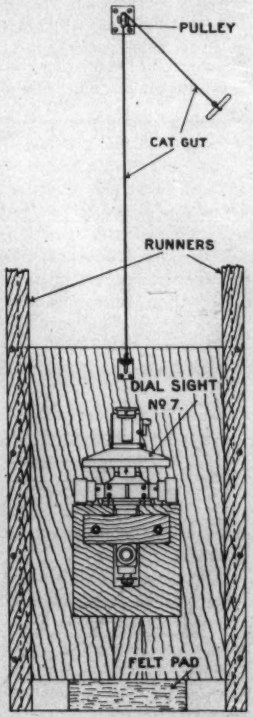

Fig. 11. Shock Test for Dial Sights.

8. The No. 7 Dial Sight is tested for definition, etc., in the same way as a telescope, and for accuracy of azimuth scale and backlash in the same way as a director. In addition, the verticality of the image has to be tested in the same way as with a prismatic telescope. Owing to the construction of the instrument it may be possible to 'lay' the cross wires on a distant object, to revolve the degree scale plate through 360°, and then find that the cross wires are not still 'layed' on the object. This is due to the fact that the centre prism revolves at only half the speed of the degree scale plate; and, if the former does not revolve accurately around the optical axis of the sight, the image of the distant object will be received upon different parts of the diaphragm, depending upon whether the reflecting surface of the centre prism is to the front or to the rear.

The fit of the Dial Sight in its carrier is very important, and certain parts have to be accurately checked with gauges. To ensure that the Dial Sight will keep in adjustment, and that specks of dust will not accumulate on the diaphragm, it is fixed in a box, Fig. 11, which is raised by means of a cord passing round a pulley and allowed to drop from a height of about 2 feet on to a thick felt pad.

9. The principal tests for clinometers are to see that the bearing-surfaces are true and at right angles to one another, that the pivots, main screws and backlash pieces are correctly fitted, and that the scales are accurate.

Fig. 12 shows the apparatus for testing the scales. It consists of a frame upon which is held by trunnions a table for supporting the clinometer. The front of the table can be elevated by means of the handle. Below the table a telescope is mounted, its trunnions having the same axis as that of the trunnions of the table. It can be elevated independently of the table, or be clamped to it and given slight adjustments by means of a slow motion gear.

Some 35 yards away from the table is mounted a scale graduated to read single minutes at the lower angles and reading up to 15 degrees. It is made of well seasoned wood, the graduations being formed by pieces of celluloid or vulcanite hammered

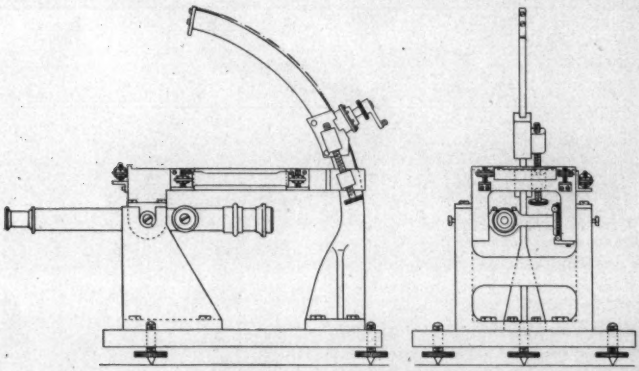

Fig. 12. Apparatus for testing Clinometers.

into saw cuts in the wood. It is so placed that it can be used by four testing apparatus.

The clinometer to be tested is placed on the table, set to zero, and its bubble brought to the centre of its run by means of the handle. The telescope is then accurately 'layed' on the zero of the wooden scale and clamped to the table. The clinometer is then set at any desired angle and its bubble brought into the centre of its run by elevating the front of the table. The telescope should then be found to be 'layed' on the same graduation on the wooden scale as that to which the clinometer was set.

When the clinometer has been tested up to 10 degrees, the table is left at that angle, and the telescope is reset to zero. In this way it can be tested up to any angle.

The truth of the bearing surfaces is tested by giving them a slight film of rouge and rubbing them on an accurate surface plate. Rouge will be left on the parts which do not bear truly.

The most convenient way to ascertain if the two surfaces are at right angles to one another is found to be to set the table of the testing apparatus at an angle of

45 degrees, then to set the clinometer to approximately 45 degrees and move its drum until the bubble is in the centre of its run.

The clinometer is then rested on its other base, and the bubble should again be found to be in the centre of its run.

10. A very large number of other instruments are inspected; but it would be impossible to give details of all the tests. The following may however be of interest.

Barr and Stroud range-finders, after having been examined optically and mechanically and heat tested, are subjected to a bumping test, to see that they will keep in adjustment. They are dropped on each end and on their side from a height of about 2 feet on to a thick felt pad. It is found that these wonderful instruments, which have to measure angles of less than 1 second, maintain their 'coincidence' adjustment under this severe test.

The flatness of heliograph mirrors is tested as follows. A man with a binocular stands behind a board on which are painted squares and circles. The mirror is mounted in a lathe chuck about 30 feet away, in such a way that the reflection of the board can be seen in the mirror. The mirror is then slowly revolved. If it is truly flat, the squares and circles appear to remain stationary; but if it is not so, they appear to wriggle about. Much difficulty has been experienced in convincing makers of the fact that mirrors must be very carefully mounted, or they very easily become strained. If possible they should bear against three equally spaced points, and be pressed against them by three springs which must press exactly opposite the points.

Bubbles have to be very carefully tested. Those for 'laying' guns must possess properties very different from those used with such instruments as theodolites.

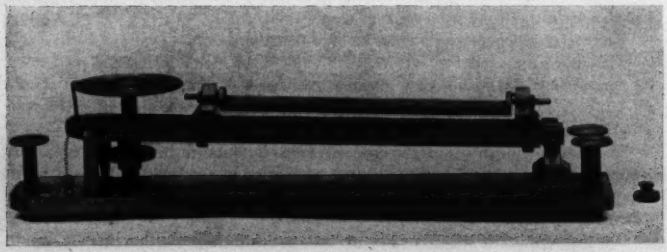

Fig. 13. Apparatus for testing Bubbles.

They must move quickly and be nearly dead beat; but they need not be very sensitive. Also as one of the wheels of the gun carriage may be on higher ground than the other one, the inside of the glass tube must be so shaped that the air bubble remains central even when the tube is rotated about its axis through some 10 degrees.

The test for sensitiveness may be divided into two parts. The air bubble is brought into the centre of its run and the tube is then slowly tilted through a small

angle (varying from half a minute to two minutes for different natures), the air bubble must move through at least half a division and must come to rest within 1 second. The tilting is then continued and the air bubble must advance through one division with a tilt of not less than, say, 30 seconds and not more than, say, 35 seconds.

As is well known, when a bubble is heated, the air bubble contracts and then disappears. Further heating bursts the glass. Bubbles are therefore heated up to various temperatures, but some of the smaller ones cannot withstand a higher temperature than 130° F.

The testing machine is shown in Fig 13. One or more bubbles are placed in the trough and their sensitiveness tested by means of the screw with scale. The air bubble being then brought to the centre of its run the trough is revolved on its axis through 10 degrees.

11. Stands have to be very carefully tested to see that they are sufficiently rigid.

Leather cases and boxes have to be tested to see that they will take the instruments snugly. As they are very frequently purchased from firms other than those who make the instruments, this is very important. The chief defects met with in leather cases are that the stitching is not correctly ended off, and that they are so shaped that the instruments, especially prismatic binoculars, are difficult to withdraw. Also there have been many instances of leather hinges of cases having been so deeply scored that they would soon break through.

12. The following are some of the defects in instruments which are sometimes met with:

The silvering of mirrors is often unsatisfactory, and sometimes after being for a few years in the tropics the mirrors are unserviceable.

Balsaming of lenses and prisms is often unsatisfactory.

The lubricant used for eyepieces of binoculars, etc. is often unsatisfactory. Its consistency should not vary much with changes of temperature, and it should allow of a smooth movement of the eyepiece. Also it must not give off any vapour which might tend to film the glass.

The exterior finish of instruments often leaves much to be desired, especially bronzing and lacquering, and the protective coating of steel parts. Enamel is not always sufficiently hard and adherent, and is sometimes too shiny; it should have a dull matt surface.

Internal optical black is nearly always not sufficiently adherent. It would probably be better to do without it and rely upon stops cutting out stray light.

Screw threads are often badly formed and fitted. In some instances it has been found possible to push a screwed cell into its tube without turning it.

Screwed cells are very often not screwed right home.

Pieces of metal are sometimes found inside an instrument; their presence being accounted for by the fact that, after the instrument had been assembled, holes for keep pins or screws had to be bored; but the instrument had not again been dismantled for removing the pieces of metal which had entered through the holes.

Scales have sometimes been found to be incorrectly divided, there being perhaps 11 divisions for 10 degrees.

By far the most troublesome defect has been dirt and film on graticules, lenses, and prisms in enclosed instruments. This subject is a very difficult one, and cannot be considered in detail here.

13. It appears to me that much research is required, and that the newly formed British Scientific Instrument Research Association will in time be able to give very valuable assistance to manufacturers and, I hope, also to my department.

I would suggest that the following subjects might be considered at an early date.

A reliable test for the weathering properties of glass.

The best method of silvering mirrors.

Tests for the quality of balsam, and the best methods of employing it.

The best protective coatings for brass and steel instruments.

The best lubricant for eyepieces, etc.

The best composition of aluminium alloys for tubes, binocular bodies, drop forgings, etc.

The best methods of cleaning glass surfaces.

The best methods of removing dust and moisture from the interior of enclosed instruments, and for making the latter as nearly airtight as possible.

14. No mention has been made of prismatic compasses, theodolites, sextants, or instruments used by the Royal Navy or the Royal Air Force, as they are not inspected by my department. A number of other instruments used with anti-aircraft and coast defences are inspected by me; but being of a somewhat confidential nature they have not been referred to.

From what I have said it might possibly be thought that the work of the optical manufacturers is not considered to be altogether satisfactory. Such is very far from being the case. The vast majority of instruments which have been passed into the service have been made in an entirely satisfactory way, and are at least equal to those of foreign origin which I have seen. The optical industry deserves the greatest credit for the way in which output has been increased without the standard being lowered. The way in which firms have been able to supply thousands of instruments when before the war they supplied only tens in the same period, is beyond all praise, especially when it is remembered that many of their best employees were taken away from them.

Before concluding I must express my great indebtedness to Mr Morrison of the Optical Munitions Branch of the Ministry for his great kindness in preparing the most excellent lantern slides which you have seen, and without which it would have been impossible for me to make certain points clear.

DISCUSSION

The President (Prof. Cheshire) said that this was the first instance he knew of in which the Head of an important Government Department had come before a scientific society to explain and to submit to criticism the methods employed in his Department. Col. Williams was in the witness-box, and he hoped that the manufacturers present would avail themselves of the unique opportunity to examine and cross-examine him.

Mr S. W. Morrison said that he himself occupied a position intermediate between Woolwich and the manufacturers, being in charge of the Optical Supply Department of the Ministry of Munitions, and that very difficult situations would have arisen had it not been for the good will manifested by both parties. He was satisfied that, however stringent the Woolwich tests were, the contractors had always received fair treatment. He had seen in some contractors' works even more severe tests than those applied at Woolwich. He thought the general standard of work had greatly improved of late, owing to the experience gained in dealing with production in quantity. There should be a great future for the optical industry as a result of the experience gained during the war.

Dr R. A. Sampson thought that in the case of shock tests nothing but some manufacturer's trick could prevent change of the optical parts. In almost any instrument it would be an easy matter to effect internal changes if one knew exactly where to apply the external shock.

He would like to see all testing establishments such as Woolwich and the National Physical Laboratory centralised under one direction for the purpose of facilitating the exchange of ideas and methods, without interfering with the special points on which service men lay great weight.

Mr R. S. Whipple wished to confirm Mr Morrison's remarks. Speaking as a manufacturer he had always met with the greatest courtesy from Col. Williams, although they had been unable to agree on all points. He complained of the difficulty manufacturers had experienced in the past in not knowing exactly what instruments were required for military purposes, and advocated the institution of some mechanism whereby manufacturers could co-operate with those who were requiring the instruments and who were responsible for testing them. He would like to point out to Dr Sampson that the Barr and Stroud range-finder could stand practically any shock test.

Dr Sampson asked if it could be dropped horizontally across a log without injury.

The President said that the Barr and Stroud infantry range-finder had been developed because of the encouragement received from the French Government, and that it had been successful in competition with the Germans in all European countries except Turkey, which insisted that range-finders should be made to resist such a shock test as Dr Sampson had just mentioned. A German manu-

facturer secured the contracts with Turkey by ribbing the interiors of the range-finders.

Mr T. Smith remarked that the Woolwich tests were very similar to those used at the National Physical Laboratory. There was one test employed at the N. P. L. however, which the author had not mentioned. Instruments intended for the Navy were given a bath in warm water to make sure that they were water-tight. Warm water was used in order that, if an instrument leaked, some water would be sucked in when the instrument was taken out of the bath and allowed to cool for a little before being dried. The presence of moisture inside the instrument could then be detected. In one or two particulars he disagreed with Col. Williams.

Instructor-Commander T. Y. Baker considered that it would be a very great advantage if designers of optical instruments could see them and use them under service conditions. The ordinary service user of scientific instruments is not a scientific man, and it is of no use giving him an instrument that can only be used by a highly trained scientist. Rather than do that it is better possibly to sacrifice some of the accuracy in order to get an instrument that is easier and more comfortable to use and that is above all things fool-proof.

Mr H. F. Purser thought that only a very accomplished examiner could test the draw tubes of a telescope in the manner that had been demonstrated without damaging the instrument.

In designing an instrument one should consider the treatment it would undergo, (1) during transit and (2) in actual use. He was of the opinion that the users of optical instruments should receive more training so that greater care could be exercised in using the instruments, and consequently instruments of less heavy design could be employed.

He thought that the use of locking screws should be abandoned, as in every case they destroyed the threads, in the making of which so much time and labour had been expended.

In connection with the question of being able to take binoculars, etc. to pieces, one was faced with the problems of locking screws and of filming. He had hoped that the author would have given more information with regard to filming. His personal opinion was that 'film,' being a natural product of atmospheric conditions, would never be entirely overcome. He had in his possession camera, cinematograph, and binocular lenses of British, French, and German design, in all of which there were traces of 'film.'

With regard to the incident of a telescope being rejected on account of its not giving good definition when the smallest holes on the definition board were used, he would like to know if the telescope was eventually passed. He had found in exhaustive tests on shooting targets that the definition of a telescope was very greatly affected by the atmospheric conditions.

Mr T. F. Connolly said that he had knowledge both of the departmental and contractors' side of inspection of stores. The presence of Col. Williams to explain methods of test and underlying principles was a matter for congratulation to the Society. When contractors had met with difficulties in connection with rejections,

he had always advised them to get into immediate touch with the inspectors at Woolwich, with the result that most of the difficulties were soon cleared up.

Mr A. G. Williams stated that in testing prismatic instruments for verticality of image the result depended on which eye was used. Slopes in opposite directions were often met with when first the right eye and then the left eye was employed for observing. At the National Physical Laboratory verticality of image was also tested on the parallelism bench.

He would like to know what methods were used at Woolwich for testing the collimation of such instruments as high-angle sights where it was impossible to get a direct rotation on bearings.

The President said that the question of design was an exceedingly important one. When he was at the Ministry of Munitions in 1915 he found that many of the specifications had obviously been drawn up by people who were quite unfamiliar with workshop practice, or in the other case by very clever designers who were entirely ignorant of service conditions. One gentleman, who was a very skilled mechanician, was continually sending in designs which had to be turned down for this latter reason. The speaker had recommended that an officer familiar with service conditions should be detailed to help this gentleman, and the result was entirely satisfactory. In the future every specification should be referred to experts in workshop practice and service conditions before being finally approved. In the case of rejections during the war Col. Williams had always invited personal interviews at which the matters were thoroughly dealt with.

The reason of having a double rectangle in the Zeiss instrument referred to in the paper was as follows. Messrs Zeiss had consulted the leading German physiologists with regard to the angular limits within which one eye can safely be turned upwards, downwards, inwards, and outwards with respect to the other eye. The result of their investigation was the outer rectangle, the inner rectangle representing the limits of actual construction.

He did not believe in tests such as the one applied to telescope draw tubes, because the severity of such a test would almost certainly in practice depend upon such extrinsic considerations as the digestive power of the inspector's stomach. He thought also that an inspector would be influenced, consciously or unconsciously, by the maker's name on the instrument.

Mr W. J. Stockwell communicated the following remarks. The question raised by Mr Purser with regard to the destruction of screw threads by locking screws could easily be solved by fixing the locking screws in holes drilled through both outer and inner tubes.

Mr James W. French communicated the following remarks. With a little thought and a little scrapping it is possible to get out of most difficulties of design and manufacture. But to devise a comprehensive specification that cannot be read in a variety of ways in the one impossible thing.

If the aim of the maker is to supply, and the object of the inspector to accept, an article that will fulfil the desired requirements, it is easy to adjust any differences that may arise. But if the inspector sees only the wording of a specifica-

tion and the maker only his curves of output or cost, then disagreement is not improbable.

The most fruitful source of such disagreement is doubt as to the methods of inspection. In removing this danger by publicly discussing his methods, Colonel Williams has extended a practice which has been greatly appreciated throughout the war by those of us who have come in contact with the Optical Inspection Department at Woolwich, which has so greatly assisted and stimulated the industry.

Although it is not always possible to correlate the works and inspection tests, it is advisable wherever possible to make the former somewhat more stringent than the latter.

In the case of optical munitions of war that must be transported in springless vehicles, shock and ageing tests throughout the course of manufacture are of the utmost importance. Screws whose fit depends only on hard binding up will certainly come adrift and oval holes will soon wear slack. The ageing test is the sieve that sorts out the bad work and saves the inspector's time and the manufacturer's reputation.

Reference has been made to a Turkish shock test, namely the dropping of the competitive instruments across a log from a height of a metre. The particulars are briefly as follows:

The competitors were Hahn, Zeiss, and Goerz, of Germany, and Barr and Stroud. The last three competitors produced instruments of service weight designed to withstand the usual gun shock and field transport tests. Hahn, with an excellent knowledge of his clients, produced an instrument remarkable for its robust appearance but which did not regard too seriously such questions as weight or rangetaking. When the log test was introduced as a pleasant Turkish surprise, the tubes of the Zeiss, Goerz, and Barr and Stroud range-finders became bent, whereas the Hahn tube survived. The Hahn instrument was then accepted.

If Dr Sampson is specially interested, I could design and supply a range-finder that would not only survive the Turkish log test but could be run over by the heaviest pattern tank and thereafter be accurate to within half a second of angle or one part in half a million, but I would not guarantee a weight of nine or ten pounds. I can assure Dr Sampson that Colonel Williams has discovered long ago all the best places to hit a range-finder.

The testing of an instrument depends very largely upon its function. Woolwich has been concerned with munitions intended to withstand field conditions. But there are optimists among us who expect that very soon there will be no optical munitions to test. Their place will be taken by instruments of peace designed to satisfy more gentle tests, which I hope will be undertaken by some authoritative institution such as the National Physical Laboratory.

There will be no need, I presume, to design a microscope to withstand a six foot drop on to a concrete floor and be able to resolve the detail of *Amphileura Pellucida*.

If the optical industry is to be wholly diverted to peace products, it is to be hoped that the great experience of the Woolwich Optical Inspection Department

will be made full use of, because, however different the conditions may be, there is much that is common as regards the workmanship and methods of construction. Indeed the future of the industry depends upon competent, strict, and yet sympathetic inspection by thoroughly trained inspectors of some approved institution, equipped with really efficient and practical testing appliances.

The author, in reply to Mr Whipple, said that he would like to see British manufacturers bringing instruments to the notice of the authorities as had been done by the firms Goerz, Zeiss, Hahn and others in Germany.

He hoped that someone would suggest a better test for telescope draw tubes, but the one they used at Woolwich had been found very satisfactory.

He thought that locking screws were absolutely necessary, otherwise eyepieces would fall out, even though the fit was very good.

The subject of filming was a very wide one, but he considered that the difficulty could be overcome. He had to be very strict with regard to filming, for he could not take any risks in sending out instruments to be used by the troops, especially in far distant fields. With regard to the telescope test he thought that the maker referred to was eventually able to get his instruments passed. In considering the question of atmospheric conditions affecting the definition it should be remembered that a telescope under test is compared with a standard one, and that both are similarly affected.

In answer to the points raised by Mr Williams the author stated that verticality of image was also tested in the Zeiss instrument. A special stand was used for collimating such instruments as high-angle sights, but he considered the point was not a very important one.

He agreed with the President that the maker's name on an instrument would have, and rightly so, some effect on the inspector who was applying such tests as that referred to. If a maker were known from experience to send in unreliable stores, his supplies would be tested more rigidly than those from a maker who usually sent in reliable ones. In no case, however, would the stores receive a more severe treatment than that which they would probably receive under service conditions.

ABSTRACTS

"The Compressive Strength of Glass and Quartz." By G. BERNDT, *Verh. d. D. Phys. Ges.*, 19 (1917), 314.

The 30,000 kilogram testing machine in the laboratory of C. P. Goerz's optical works was employed for testing the compressive strength of glass and quartz. The specimens, which were in the form of cubes, were placed between hard steel plates which were accurately ground plane and polished, and the pressure was increased continuously until the specimens broke into small pieces. Cubes of mirror glass were first experimented with, and the results varied with the size of the specimen, as the following table shows:

Length of side mm.	Mean value kilos/cm.^{2}	Maximum value kilos/cm.^{2}
5	12000	13000
8	10300	10400
10	9000	10000
15	8700	8800

The two surfaces of each specimen in contact with the steel plates were ground plane and polished, while the remaining four faces were in some cases polished and in others only finely ground. One would expect that the specimens with the ground faces would break sooner than those with polished faces, but this was not so. Nevertheless in the later experiments polished specimens were employed. In some cases specimens broke up prematurely, due probably to the presence of fine cracks on the surface. These specimens were not taken into account in calculating the mean values.

A very interesting observation was made in the case of a cube, the length of whose side was 5 mm. It was loaded up to 3000 kilograms. On removing the pressure, a crack was found to have developed in such a way that a central cylinder of glass was left. This shows that in a cube the portions of the glass near the edge have less to do with the compressive strength of the specimen than the central cylindrical portion. The remaining experiments were therefore made with cylinders.

In order to obtain accurate measurements optical glass must be used, because its constitution is better known and it possesses greater homogeneity and less internal strain than ordinary mirror glass. Accordingly experiments were carried out with a Boro-Silikat-Kron 516/640 of the Sendlinger optische Glaswerke; this glass is similar to the Jena glass O 3832. Two pieces of the glass from the same melting were heated in an oven until they took up the form of plates. One of the plates was taken out at 600° C. and allowed to cool in the air, while the other was very carefully annealed. The specimens, in the form of cylinders 5 mm. in diameter, were cut from these plates; with some of these the load was increased continuously, while with others it was increased by steps of 100–200 kilograms. The results are given in the following table:

	Load increase	Mean value kilos/cm.²	Maximum value kilos/cm.²
Strained glass	Continuous	15000	18400
	By steps	15200	17500
Annealed glass	Continuous	14200	16900
	By steps	12500	15100

Experiments were carried out with cylinders of quartz. The specimens frequently splintered, and on account of the greater hardness of quartz the steel plates were very strongly affected. The results for quartz are as follows:

	Mean value kilos/cm.²	Maximum value kilos/cm.²
Parallel to optical axis	25000	28000
Perpendicular to optical axis ...	22800	27400

J. S. A.

"The Nomenclature of Optical Glass." By W. ZSCHOKKE, *Z. f. Instrumentenkunde*, 38 (1918), 49.

This paper contains an interesting account of the history of optical glass nomenclature. Although lenses were constructed for optical purposes in the 13th century, the conception of the term "optical glass" dates from about the middle of the 18th century. Flint glass received its name from the fact that flint powder is used in its manufacture. The term "crown" glass has its origin in a very old method of making the glass. With the help of a tube about 2 metres long 8–9 kilograms of the glass were taken out of the oven and blown out into a large bubble, which became flattened on rapidly rotating the tube. A long iron handle was then attached to the opposite end of the bubble and the tube detached. The glass was again introduced into the oven and the iron handle rapidly rotated. On account of the centrifugal force the bell of glass took the form of a crown and then that of a round flat disc.

Guinand was the first to make optical glass free from striae and bubbles. He carried out his research work with Fraunhofer. They were the first to manufacture large pieces of glass. The term "Crownglas" was used by Fraunhofer and was adopted in the first catalogues of Messrs Schott. In 1902 the term was replaced in Schott's catalogue by "Kronglas."

After Fraunhofer's death the art of making optical glass deteriorated in Germany, while it was introduced into France by Guinand and later into England by Bontemps. Technical improvements were introduced, but, although some progress was made by Harcourt, the scientific side was not greatly developed. Thus Messrs Chance Bros. have in general made meltings of only five glasses—

Hard Crown	Hartkron
Soft Crown	Weiches Kron
Light Flint	Leichtflint
Medium Flint	Gewöhnliches Flint
Extra Dense Flint	Schweres Flint

The terms "hard" and "soft" are very probably derived from the melting properties of the glass, but they also fit in with the mechanical hardness, whereas the terms "light" and "dense" relate to the specific gravity.

The French use the terms "très-léger," "léger," "ordinaire," and "lourd" for crown glasses and "très-léger," "léger," "dense," and "très-dense" for flint glasses, and they employ the density for specifying the individual meltings.

The new glasses which Messrs Schott and Gen. introduced in 1886 had the property of high refractive index combined with small dispersion. New terms, such as "Boro-Silikat-Crown," "Barium-Silikat-Crown," and "Barium-Phosphat-Crown" were employed.

Abbe used five bright spectrum lines for determining the refractive properties of the glasses. These are as follows:

Light Source ...	Potassium	Hydrogen	Sodium	Hydrogen	Hydrogen
Designation ...	A'	C	D	F	G'
Wave-length in $\mu\mu$	768	656	589	486	434

In the glass list he gave the mean value of the refractive indices for the D lines, the mean dispersion $n_F - n_C$, the value of $\nu = \frac{n_D - 1}{n_F - n_C}$, the partial dispersions $n_D - n_{A'}$, $n_F - n_D$, $n_{G'} - n_F$ and the partial relative dispersions $\frac{n_D - n_{A'}}{n_F - n_C}$, $\frac{n_F - n_D}{n_F - n_C}$, and $\frac{n_{G'} - n_F}{n_F - n_C}$. The glasses were arranged according to their ν-values.

Designation	n_D	ν	$n_F - n_C$	$n_D - n_C$	$n_F - n_D$	$n_{G'} - n_F$	Remarks
Kron 507/628	1·5072	62·8	0·00808	0·00241	0·00567	0·00453	Similar to O. 599
510/634	1·5100	63·4	0·00805	0·00240	0·00565	0·00451	,, ,, O. 144
511/638	1·5114	63·8	0·00802	0·00239	0·00563	0·00448	
511/643	1·5110	64·3	0·00795	0·00236	0·00559	0·00443	
512/603	1·5117	60·3	0·00848	0·00251	0·00597	0·00480	,, ,, O. 6223
516/640	1·5160	64·0	0·00806	0·00241	0·00565	0·00448	,, ,, O. 3832
519/604	1·5191	60·4	0·00859	0·00254	0·00605	0·00486	,, ,, O. 3453
533/602	1·5330	60·2	0·00886	0·00261	0·00625	0·00503	
Barion 540/599	1·5398	59·9	0·00901	0·00266	0·00635	0·00511	,, ,, O. 227
563/581	1·5632	58·1	0·00968	0·00285	0·00683	0·00552	
573/575	1·5731	57·5	0·00996	0·00293	0·00703	0·00568	,, ,, O. 211
590/611	1·5900	61·1	0·00965	0·00286	0·00679	0·00544	,, ,, O. 2122
601/573	1·6009	57·3	0·01048	0·00309	0·00739	0·00596	
609/589	1·6091	58·9	0·01035	0·00305	0·00730	0·00588	,, ,, O. 2071
611/558	1·6109	55·8	0·01094	0·00321	0·00773	0·00626	,, ,, O. 3961
614/564	1·6137	56·4	0·01088	0·00320	0·00768	0·00623	,, ,, O. 2994
615/567	1·6146	56·7	0·01084	0·00319	0·00765	0·00619	
Barint 548/532	1·5480	53·2	0·01030	0·00302	0·00728	0·00595	
570/560	1·5704	56·0	0·01018	0·00300	0·00718	0·00583	,, ,, O. 7550
580/538	1·5799	53·8	0·01079	0·00316	0·00763	0·00622	,, ,, O. 722
626/393	1·6259	39·3	0·01591	0·00456	0·01135	0·00960	,, ,, O. 748
657/363	1·6572	36·3	0·01813	0·00515	0·01298	0·01106	,, ,, O. 3269
Flint 523/513	1·5232	51·3	0·01020	0·00300	0·00720	0·00586	Telescope flint
541/477	1·5409	47·7	0·01134	0·00329	0·00805	0·00666	
549/461	1·5494	46·1	0·01193	0·00347	0·00846	0·00705	Similar to O. 378
569/426	1·5693	42·6	0·01338	0·00386	0·00952	0·00801	,, ,, O. 376
571/430	1·5711	43·0	0·01327	0·00382	0·00945	0·00792	
577/414	1·5770	41·4	0·01393	0·00400	0·00993	0·00833	,, ,, O. 340
605/390	1·6049	39·0	0·01553	0·00445	0·01108	0·00935	,, ,, O. 318
613/369	1·6133	36·9	0·01663	0·00474	0·01189	0·01010	,, ,, O. 118
617/365	1·6170	36·5	0·01689	0·00482	0·01207	0·01028	,, ,, O. 167
619/377	1·6193	37·7	0·01644	0·00470	0·01174	0·00998	
620/362	1·6204	36·2	0·01714	0·00488	0·01226	0·01044	,, ,, O. 103
624/357	1·6242	35·7	0·01749	0·00498	0·01251	0·01070	,, ,, O. 93
649/338	1·6489	33·8	0·01920	0·00547	0·01373	0·01181	,, ,, O. 102

The objection to such a method of specifying the types of glasses is that it is not distinctive enough, with the result that a glass becomes known eventually by its type number. The Sendlinger optische Glaswerke G. m. b. H., which shortly before the war took over the works founded by Prof Steinheil in Munich, has introduced a new system of nomenclature. Each type of glass is designated by one of four names, Kron, Barion (contraction for Barium-Kron), Barint (contraction for Baryt-Flint), and Flint, and in addition by two three-figured numbers, the first of which gives the first three decimal figures of the refractive index, and the second is ten times the ν-value. Thus a Boro-Silikat-Kron with the values $n_D = 1{\cdot}516$ and $\nu = 64{\cdot}0$ is called Kron 516/640. The preceding table gives a list of glasses which the firm supplies.

J. S. A.